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Arguments For and Against Limitation of Length of Freight Trains

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84.	63.	August, 1915.
85.	64.	September, 1915.
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Arguments For and Against Limitation of Length of Freight Trains

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INTRODUCTION.

Origin and Extent of Movement to Secure Train-Limit Legislation.

Following in some states the defeat, and in others the repeal, of so-called "full-crew" laws, there has been a widespread effort on the part of the legislative representatives of the railway labor brotherhoods to secure substitute legislation. This has taken the form of bills, introduced in numerous states, to limit the length of freight trains. The grounds on which they urge these proposals are almost solely considerations of safety. They claim that the number of casualties on railways to all classes of persons, but especially to trainmen and passengers, is increasing and that this is due in substantial measure to the increasing number of cars handled in a single train.

In the attempts to secure so-called "full-crew" legislation, efforts were directed toward having the law prescribe the minimum number of men it should be lawful to employ on trains containing specified numbers of cars. The bills that have been advocated more recently have sought to fix either the maximum length of a train or the maximum number of cars in a train. In some cases the limit has been set at trains a half mile long; in some at 50 cars. In Illinois in 1915 the successful opposition of the railways to the passage of a bill limiting trains to 50 cars was met by an amendment placing the maximum at 75 cars. The bill as thus amended also failed.

During the winter and spring of 1914-1915 bills to limit the length of trains were introduced in the legislatures of 20 states. All of them failed to pass. These states were:

California,	New Jersey,
Colorado,	New York,
Georgia,	North Carolina,
Illinois,	North Dakota,
Indiana,	Ohio,
Iowa,	Pennsylvania,
Kansas,	South Carolina,
Michigan,	South Dakota,
Minnesota,	Utah,
Nevada,	Wisconsin.

In Arizona legislation limiting freight trains to 70 cars is in force. This is the only state in which such legislation has been passed.

Long Trains One Feature of Progress in Railway Transportation.

The proposal to limit the length of freight trains, whether for reasons of safety, as claimed, or otherwise, fundamentally concerns the whole scheme of railway operating methods. An intelligent consideration of the merits of the proposal must, therefore, take account of the important rôle that long freight trains have come to play in railway progress.

The increase in the length of freight trains has been an important factor in the steadily growing use of large train units; and large train units have constituted the cardinal feature of the increased efficiency of railway transportation in the United States. Throughout every industry, efforts to reduce the cost of a unit of product have given wide extension to large scale methods of production. The application of these methods to transportation, as rapidly as volume of business permitted, has been made through larger and larger steamships and longer and longer trains.

This use of long freight trains not only has reduced the necessity of raising many freight rates to meet the marked increase in wages and prices generally, but has permitted some reductions in rates. This benefit from large train units has inured to practically the entire population, for substantially all people are today dependent, directly or indirectly, on railway transportation for a great part, if not all, of their supply of commodities. Railway employees, considered separately as one group, have been benefited to the extent that the economies from large trains have enabled the carriers to meet successive advances in wages, notwithstanding the public's restraint upon increases in rates. Such a two-fold pressure upon the railways, namely, public demand for a lowering of rates and employees' demand for increases in wages, could not have been met without progressive economies in operation resulting mainly from the handling of freight in larger units.

Further, the increase in train load, caused in large part by the use of longer trains, has resulted in savings that have added to the fund from which permanent betterments and improvements to the

properties have been made, for the benefit not only of the public, but also of the employees working thereon.

The place of large train units, as the central factor in increased efficiency in railway operation, can best be understood by a brief review of those facts of railway development that are associated with the movement.

Number of Cars per Freight Train.

The average number of cars per freight train on all the railways of the United States increased from 26.8 cars in 1904 to 34.3 cars in 1914, an increase of 28 per cent. On the railways of the Eastern District the increase was from 28.6 to 36.4 cars; on the railways of the Southern District, from 23.8 to 30.7 cars; and on the railways of the Western District, from 26.1 to 33.8 cars. The facts are shown in Table I.

TABLE I.

FREIGHT CARS PER TRAIN.*

Year.	United States.	Eastern District.	Southern District.	Western District.
1904	26.8	28.6	23.8	26.1
1905	27.6	28.8	24.4	27.5
1906	27.9	29.3	24.4	27.8
1907	27.2	28.8	23.1	27.0
1908	28.7	30.9	24.3	28.1
1909	30.2	32.4	26.5	29.3
1910	29.9	32.0	26.8	28.9
1911	30.8	32.8	27.8	30.1
1912	31.8	33.9	28.3	31.1
1913	32.7	34.7	29.1	32.0
1914	34.3	36.4	30.7	33.8
Increase 1914 over 1904.	7.5	7.8	6.9	7.7

*Computed from Statistics of Railways in the United States, Interstate Commerce Commission, 1904 to 1914. Averages exclude mixed train mileage.

Of course, these averages include many roads with comparatively light traffic. The larger railways show averages much greater than these. And in those sections of the country where the traffic is heavy, especially where the volume of a single class of freight warrants the handling of solid trains of minerals like coal, and of agricultural products, freight trains not infrequently include from 50 to 75 cars, and even more.

On branch lines the service requires that trains be run frequently regardless of the smallness of the number of cars which it is necessary to handle. The average number of cars operated as a train is affected by the fact that such an average covers trains run in both directions and the number of cars run in one direction one day may be much greater than the number to be moved in the opposite direction. Livestock trains and those carrying perishable freight frequently are and must be moved in small units. It is only on main arteries where the great volume of business moves that long trains are common.

Capacity of Freight Cars.

The average capacity of freight cars on the railways of the United States increased from 30 tons in 1904 to 39 tons in 1914. The average load carried by freight cars increased from 17.7 tons in 1904 to 21.1 tons in 1914. Here again this average falls far short of indicating the capacity and loading attained in the sections of greatest density of freight business, and especially in the transportation of minerals. In 1914, 30 per cent of all freight cars had a capacity of 50 tons or over. Table II shows the increase in average capacity and loading from year to year.

TABLE II.

AVERAGE CAPACITY OF FREIGHT CARS AND TONS CARRIED PER LOADED CAR.*

Year.	Average capacity (tons).	Average load per car (tons).	Year.	Average capacity (tons).	Average load per car (tons).
1904....	30	17.7	1910....	36	19.8
1905....	31	18.1	1911....	37	19.7
1906....	32	18.9	1912....	37	20.2
1907....	34	19.7	1913....	38	21.1
1908....	35	19.6	1914....	39	21.1
1909....	35	19.3			

*Statistics of Railways in the United States, Interstate Commerce Commission, 1904-1914; Bulletin 81, Bureau of Railway Economics.

Train Loads.

The effect of heavier car loading and increased number of cars per train is shown in the train load. This has been increased at an even greater rate than either of the component factors. In 1904 the average load carried per freight train on the railways of the

United States was 307.8 tons. By 1914 this increased to 451.8 tons, or nearly 50 per cent. In the Eastern District, including the region of heaviest traffic, the average train load in 1914 was 537.3 tons. The progress of this growth is shown in Table III.

TABLE III.

AVERAGE TONS PER TRAIN.*

Year.	Tons per train.	Year.	Tons per train.
1894	179.8	1905	322.3
1895	189.7	1906	344.4
1896	198.8	1907	357.4
1897	204.6	1908	351.8
1898	226.5	1909	362.6
1899	243.5	1910	380.4
1900	270.9	1911	383.1
1901	281.3	1912	406.8
1902	296.5	1913	445.4
1903	310.5	1914	451.8
1904	307.8		

Increase 1894 to 1914, 151.3%. Increase 1904 to 1914, 46.8%.

On some lines the average train load is over 1,000 tons, and train loads of minerals from 3,500 tons to 5,000 tons are not uncommon.

Size and Power of Locomotives.

To haul such heavy trains the size and power of locomotives have necessarily been increased. The average weight, exclusive of tender, increased from 62 tons in 1904 to 83 tons in 1914, and the average tractive power increased from 22,804 pounds in 1904 to 30,420 pounds in 1914. The steady increase in tractive power is shown in Table IV.

TABLE IV.

AVERAGE TRACTIVE POWER OF LOCOMOTIVES, 1904-1914.*

Year.	Pounds.	Year.	Pounds.
1904	22,804	1910	27,282
1905	23,666	1911	27,949
1906	24,741	1912	28,634
1907	25,823	1913	29,702
1908	26,384	1914	30,420
1909	26,634		

*Statistics of Railways in the United States, Interstate Commerce Commission, 1904-1914.

In 1914 there were in operation on the railways of the United States 775 locomotives of the Mallet type with an average weight, exclusive of tender, of 197 tons and average tractive power of 79,021 pounds. A number of these exceeded 100,000 pounds in their tractive power.

Track, Bridges and Other Structures.

The steady introduction of larger, heavier and stronger equipment and the constant increase in weight of freight trains have required corresponding changes of every other part of the railway plant. Tracks have been relaid with heavier rails. Bridges have been replaced by stronger ones capable of bearing the heavier trains. Curves have been reduced or eliminated. Grades have been cut down. Passing tracks have been rebuilt to accommodate the longer trains. Water supply and coaling stations have been enlarged to adapt their capacity to the greater water and coal consumption of locomotives, and have been relocated to suit the greater distances fixed between stops in the interest of more efficient operation. Finally, terminal facilities, round-houses and shops have been improved and enlarged to accommodate the heavier equipment, or in some instances have been relocated to reduce the length of run.

In order that at the outset a comprehensive view of the problem of limiting train length may be had, the arguments for and against the proposal will be stated in order and without discussion.

SUMMARY OF ARGUMENTS FOR AND AGAINST LIMITING THE LENGTH OF TRAINS.

Arguments for Limiting Train Length.

The principal arguments presented for train-limit legislation may be summarized as follows:

1. It is difficult to transmit signals by hand or lantern from the rear of a long train to the engine. Hence, there is frequent failure of enginemen to receive or to understand such signals, and an increase of accidents by reason of such failure.

2. Because of the greater aggregate weight of the cars in a long train, there is more strain on the draft gear of the cars near the locomotive. Therefore, there is more risk of accident from the pulling out of drawbars or the breaking of knuckles or knuckle-pins. Also, the greater momentum of a long train puts a harder strain on the brakes of the forward cars when the train is stopped and hence entails greater possibility of failure of brake gear.

3. In coming to a stop, especially when stopping suddenly as in an emergency, or when, by the bursting of an air hose or otherwise, brakes are automatically set, the liability of the train "buckling" is greater in a long train than in a short one, and the risk of collision from passing trains is increased. The reason assigned for this claim is the fact that in applying air brakes from the locomotive the brakes on the cars nearest the engine set first and then, in turn, those next behind, and so on until the rear cars are reached. Now, the interval of time between the first check upon the speed of the forward cars and the final slackening of the rear cars is greater on long than on short trains. Hence it is urged that there is greater opportunity and risk of a "bunching of slack," in the course of which the unchecked momentum of the rearward part of the train can exert a pressure upon the already retarded forward cars sufficiently powerful to force the intervening cars to one side.

Because of the greater amount of "slack" in the draft gear of long trains, more severe shocks result from the sudden stopping of the train. This is claimed to be particularly the case when the brake action on the forward cars is more effective than on the cars in the rear part of the train. In addition to the risk of buckling.

it is claimed that such severe shocks are liable to cause injury to men upon the rear of the train, throwing them from the cars or knocking them down in the caboose. In short trains there is less slack and therefore, it is maintained, less liability of injury resulting from emergency stops.

4. Liability to accident from defective equipment is greater in long than in short trains, it is contended, because:

(*a*) The strain upon draft gear, brake rigging and the body of the car is greater in long than in short trains. Hence, the liability of parts of cars becoming defective is intensified by the use of long trains. Not only is the number of such defective parts in a train likely to bear a certain relation to the number of cars in the train, but

(*b*) There is greater likelihood that such defects will escape detection in the inspection by trainmen during stops on the road, since the cars in a long train are likely to be inspected more hurriedly than in a short train.

5. More time is required for stopping and starting long, heavy trains, when it is necessary to do so to avoid accident; hence, there is greater risk of accident from situations that might be harmless in the case of short trains.

Arguments Against Limiting Train Length.

All of the arguments advanced for train-limit legislation are directed against the alleged danger of the long train as a *unit* of operation. They take no account of other factors affecting safety of operation as a whole that would be influenced by restrictions on train length. For this reason the case against train-limit legislation distinguishes two groups of arguments on the question of safety:

1. The claim that, whether for any or all of the five reasons given, the operation of a long train necessarily or ordinarily involves more risk than that of a short train is not, it is contended, sustained either by an analysis of the various elements affecting safety, or by the available statistical evidence.

2. Reducing and limiting the length of trains necessarily means that more trains must be operated to handle existing business, and that there must be even more than a proportionate increase in their

present number in order to care for additional business in the future. Crowding the railway lines with more trains, a necessary consequence of restrictions in the number of cars operated as a single train, will give more chances for collisions, derailments, for misunderstanding of orders because of the greater number of orders, and for any and all such causes of accidents as are likely to arise in connection with the more frequent stopping, starting, and passing of trains.

In the following pages the points thus briefly stated will be considered more at length.

RELATIVE SAFETY OF LONG AND SHORT TRAINS AS OPERATING UNITS.

The claim that long trains are less safe to operate than short trains is based on five arguments, which will now be discussed in order.

Transmission of Hand Signals.

It is claimed that it is difficult to transmit intelligible signals from the rear of a long train to the engineman on the locomotive. This claim would seem, at first thought, to have much force, but its force is greatly impaired, if not destroyed, by the changes in methods of operation and train control which have accompanied increases in the length of trains. Even if the claim is true, it has little bearing, it is insisted, on the question of limiting train length.

In the class of service usually performed by long trains, the necessity of exchanging signals between the rear and the engine is much less frequent than on the shorter trains that do junction or local work. Long trains are ordinarily operated in through service. They move as a unit between division points with few or no stops for local service at stations. To avoid interruptions in their movement, they ordinarily have the right of way over shorter trains performing station service. In certain instances they have the right of way over the less important passenger trains. Except to take on supplies of coal or water, or for unforeseen contingencies, they usually make no stops between division points. And these few occasions for stopping are previously known by the engineman without need of communication from other trainmen at the rear. Ordinarily, therefore, there is little occasion for the transmission of signals by hand or lantern from one end of the train to the other. It is the custom on most railroads to require an exchange of signals between the front and rear ends of trains when passing stations or through interlocking plants. Such rules are carried out successfully even where 100 cars are handled as a single train. Section foremen, track-walkers, agents, operators, towermen and other employees stationed at such points are in position to give warning to enginemen and trainmen of any unusual circumstances likely to cause accident to the train.

Further, practically all cars of all trains are equipped with air-brake apparatus controlled from the engine. In case of an emergency stop, the engineman can call out the rear brakeman for flag duty by the locomotive whistle. He is recalled by the same means. In the case of need for the transmission of signals in the reverse direction, which on the road is relatively infrequent in this class of service, the engineman can be signaled, if need be, with the air signal from the caboose, or the train can be stopped by the application of the brakes from any car, though this is a somewhat hazardous operation. So, also, when a train is maneuvering, fully made up with air hose connected, there is always a chance to avoid the consequences of failure of a signal from the rear to the locomotive by air signal from the caboose. In terminal yards the length of the train, as finally made up, does not enter into consideration, for it then consists of several parts, each of which is ordinarily under the control of a member of the yard switching force who is relatively not far distant from the engine.

Finally, actual tests indicate that hand signals can be successfully transmitted from the rear of long trains to the locomotive, even under adverse weather conditions. In a hearing in February, 1915, before a committee of the Kansas legislature, C. W. Kouns, General Manager of the Eastern lines of the Atchison, Topeka & Santa Fe, described tests made with a train of 79 cars, as follows:

"We had a series of tests made on January 26, which was a foggy, damp, dark day. The train [crew] consisted of an engineer, fireman, two brakemen and a conductor. The first test was made with one brakeman on top of the car next to the engine and the other on the caboose, 3,137 feet apart. Every signal made was correctly answered and the engine was correctly moved on it on all of those tests at that distance. In the second test, we placed the men on the ground alongside the train because it would probably be more difficult to signal on the ground by hand than it would on top of the cars. These men were 3,188 feet apart; every signal was correctly transmitted to the engineer, who made his movements, without a flaw, upon each signal transmitted. Every man participating was more than forty years old."

It may be contended that such a test as this, planned beforehand and made with the employees in a specially attentive state of mind, is not entirely representative of all situations. But, as already ex-

plained, the occasions for hand signaling usually arise, in the nature of things, in connection either with scheduled stops or special stops on some signal or situation ahead perceived by the engineer. In either case the train crew's attention is specifically drawn to the signaling to be done. The situation is practically identical with that in the special test. That test indicates that, whatever the difficulties presented by long trains, they can be overcome with due care and attention. Hence, the only additional risk from length of train in hand signaling is that springing from the decline in alertness that arises when operations become habitual. But the remedy for this would seem to be a recognition by the employees of their own claim that operations with long trains are somewhat different from ordinary operations and that they require therefore such a degree of care as would be taken in a special test.

Considering, then, the relative infrequency of occasions for hand signaling in the service in which long trains are used, and considering that on far the greater part of such occasions as do arise any special risk due to length of train can be met by recognizing that there is special risk and by giving the work special care and attention, railway managers insist that limiting the length of trains is hardly a rational solution for the difficulties of hand signaling.

Failures of Draft Rigging or Brake Gear, Parting of Trains, etc.

It is claimed that increasing the number of cars in a train increases the liability of accident to trainmen on account of the greater danger of failure of draft gear or brake rigging, or of parting of trains. This assumes that the increase in the strength of the cars themselves, as well as improvements in draft gear and braking apparatus, have not kept pace with their increased number per train.

It can be answered that probably no features of the equipment of cars have been subjected in recent years to more careful study and improvement, to render them adequate to the augmented load, than draft gear and brake rigging. Both have received the benefit of the combined study of manufacturers and railway officers, expert engineers and employees. Both the construction of the freight car in detail and the sufficiency of its attachments are subjects of constant investigation by the Master Car Builders' Association. Changes in standards and recommended practice follow closely the appearance of a necessity for increased strength.

If it were admitted that failures of draft gear or brake apparatus are more frequent than formerly, this, it is said, would indicate merely that the improvement in the design of cars for strength of construction and equipment has not yet fully met the demands of heavier trains. Obviously, the remedy for such a situation lies in bringing the strength of equipment, including that of attachments, up to the standards that progressive experience is showing to be necessary in the operation of long trains, rather than in drastic proposals that would result in throwing away all the economic advantages secured from long trains. This progress, as already said, the railways are rapidly making. Meanwhile it is common practice, so far as it is necessary to use them in long trains, to provide for the location of the weaker cars at points in the train where they will be subject to the least strain. But ordinarily they are employed in service in which shorter trains fulfill the requirements of traffic.

Buckling of Trains.

It would be correct to say that, as an abstract proposition, and other things being equal, long trains are subject to greater risk of buckling than short trains. For it is true, as a general statement, that the longer the train the longer will be the interval before the application of the brakes on the rear cars will cause a slackening of their speed uniform with that of the forward cars. It is also true that, if frequent stops were made by long trains under emergency conditions and if there were a considerable number of empty cars on the front end of the train, there might occur such a "bunching of slack" as would produce a severe shock from the impact of the cars in the rear. But, it is urged, speaking concretely and with regard to actual conditions, long trains are not made up and operated "other things equal" with short trains. In long and heavy through trains there is not the same necessity for making up in "station order" as in the case of short trains performing local service. Instructions are therefore commonly given for the distribution of empty cars through the long train to prevent the possibility of the slack "bunching." Moreover, air-brake manufacturers have anticipated non-observance of such instructions and furnish a "light and load" brake which maintains the same relative braking power upon the empty car as upon the loaded car.

Again, it is pointed out that emergency stops are less frequent

with long and heavy trains than with short trains, because of the nature of their customary service and because of the rights allowed them on the road; that air brake hose does not regularly burst and set brakes suddenly; that enginemen are invariably instructed, in applying brakes, to manipulate the controlling valve with regard to the length and weight of the load behind the tender. If the brake is properly manipulated, there is no reason why in ordinary service a long train should not be brought to a stop with little or no shock and without undue strain upon car sills or draft gear. It thus appears that, because the service in which long trains are ordinarily engaged is of such a character that stops are infrequent and the speed is lower, the occasions and conditions in which sudden stops might produce buckling are few. In ordinary stops the situation is entirely within control of the engineman, whose skill and carefulness are the determining factors.

So far as strains upon brake apparatus are concerned, it is asserted, the argument is in favor of the long train. Short trains ordinarily move at higher speed between stops than long trains and in stopping subject brake equipment to more severe strains.

A method of administration could hardly be defended which should prepare for the *occasional* situations in which emergency stops might be disastrously made, or for *occasional* carelessness on the part of the engineer in ordinary stops, by restricting, in *all cases,* such an important factor of railway operating efficiency as length of trains.

Detection of Broken Car Rigging En Route.

The argument for limiting train length on the ground that breakages in draft gear or brake rigging, or other defects, occurring on the road are more liable to escape detection in long trains than in short, has this weakness. The risk claimed from this source may be regarded as due either to more frequent breakages en route under the strain of long trains, or to greater difficulty of detecting such as do occur, in view of the length of the train to be inspected in the time available during stops. With respect to the first view, it is claimed that the proper remedy,—already being applied,—is to continue the steady improvement in the strength of equipment and the steady substitution in long trains of newer and stronger cars for older and weaker ones. In this view, the risk, whatever it may be,

is temporary. With respect to the second point of the argument, rigid terminal inspection of trains before departure leaves for consideration only breakages that develop on the road. As to these, it is to be noted that they occur under the sudden strains of such operations as stopping, starting, and backing; and that, in the service in which long trains are used, these operations are relatively infrequent. Hence the conclusion is reached that whatever the additional risk of a permanent character from the difficulties of inspecting long trains may be, it cannot be of an appreciable amount, and thus would be far from justifying the policy of a limitation of train length.

Possible Promptness of Control of Long Trains.

The final argument for limiting train length is that long trains can be stopped or started only with comparative slowness. Hence, in any of these recurrent situations in which a collision or some other accident is impending and can be avoided by promptly stopping a moving train, or starting one at rest, the chance of avoiding such an accident is reduced by the greater time necessary with a long train to perform the needful movement. This claim is true to the extent that brakes must be applied to long trains more gradually than is permissible with short ones, in order to avoid danger of buckling, as already explained, and to the extent that a heavy train cannot be gotten under way so promptly as a light one. But, as between a train of nearly fifty cars and one of many more than fifty cars, there should ordinarily be no difference in the requirement of careful manipulation of brakes. A sudden or severe application is not permissible in either case except in emergency. Then the emergency must be met regardless of the length of train. Over against the additional risk from this source, railway men strongly urge that there should be considered the great increase in the number of threatening situations that would follow the multiplication of trains on the road, if their length is limited, in order to move the same volume of business. This point is developed more fully later on. But it needs no explanation to see that if the *opportunities* for accidents are increased, the additional accidents actually happening on that account may well be far in excess of the number that would be avoided through the greater mobility of short trains.

Conclusion.

The foregoing general analysis of the arguments against long trains shows the following weakness to be common to all except the last. The hazard in train operation lies mainly in maneuvering—in starting, stopping, backing and switching—and in speed. But the service in which long trains are used is one in which these operations are relatively infrequent, and in which the trains run at a more uniform speed, which is slower than that commonly attained by shorter trains in local and way service. Therefore, it is considered obvious that the maximum possible effect that the length of the trains in through service can have on that large proportion of casualties which arise from train operations is less than might at first seem possible in view of the arguments advanced.

This conclusion will appear, also, from an examination of such data as are available for making a comparison of the number of casualties with long and short trains. Entirely pertinent statistics showing the comparative measure of risk in the operation of long and short trains are not available. There are, however, some statistics that have an important bearing on the question.

STATISTICS REGARDING COMPARATIVE NUMBER OF ACCIDENTS TO LONG AND SHORT TRAINS.

The advocates of train-limit legislation support their principal claim that long trains have caused an increase in accidents by reference to the accident statistics of the Interstate Commerce Commission. But no definite and relevant comparisons have been produced by them to show that such casualties have shown a tendency to increase with the increase in length of trains. The extent to which such statistics have been employed is limited usually to general statements that casualties due to railway operations are increasing from year to year. When more specific and definite comparisons have been made, they have failed to distinguish accidents that might, on the basis of their general reasoning, be considered as possibly related to long trains and accidents that cannot, on any reasoning whatever, be even remotely affected by long trains. It ought to go without saying that, to prove anything concerning the danger asserted to lie in long trains, the statistics offered in proof must be limited to accidents of such a nature as can be seen to have some relation to the length of the train, and must cover sufficient time and sufficiently varied conditions to be representative of actual tendencies and not abnormally affected by temporary or local influences.

An example of neglect in all these respects is found in accident statistics offered by representatives of the Brotherhood of Railway Trainmen, who appeared at a hearing before a committee of the Kansas legislature in February, 1915, in support of a bill limiting trains to not more than fifty cars. They stated that, according to the quarterly Accident Bulletin of the Interstate Commerce Commission for July, August, and September, 1901, 366 employees were killed and 1,679 employees were injured during the quarter; and that, according to Accident Bulletin No. 51, for the months of January, February, and March, 1914, 752 employees were killed and 37,315 were injured during that quarter.

The first thing to note about these citations is that they are inaccurate statements of what the Interstate Commerce Commission bulletins show. The 366 killed in 1901 were *trainmen* only. The number killed, among *all employees*, was 615. The number stated as the injured does not appear in any of the tables in the Bulletin

cited. Of trainmen alone, there were 4,619 injured, and of all employees there were 8,361 injured. In 1914, the figures quoted include all those casualties in railway shops, or otherwise than in purely railway occupations, known as "Industrial accidents," which were not reported by the Interstate Commerce Commission in 1901, but had become a part of the returns by 1914. These amounted to 79 killed and 24,679 injured. To get statistics that are really comparable with those for 1901, all such industrial accidents—which can be in no way whatever affected by the length of trains—must be omitted. That leaves 673 killed and 12,636 injured in the first quarter of 1914, to be compared with 615 killed and 8,361 injured in the third quarter of 1901.

Even after correcting these inaccuracies, and taking only the statistics just given as more nearly representing the *same classes* of employees in the two years, the statistics are still without significance for the claim that the growth of long trains has caused an increase in casualties. In the first place, three months, or even a full year, for that matter, is far too short a time to reveal a surely representative picture of *average* conditions. And in this case, the two periods were most unhappily chosen. The three months of July, August, and September, 1901, were the very first three months of the existence of the department of the Commission that studies accident reports and prepares the accident Bulletins. It is conceded by everybody that the statistics gathered during, not only the first three months, but the first year or so, were distinctly incomplete because the organization for gathering, sifting, and compiling them was not fully worked out for some time. It will be clear to everyone, then, that no significance for the present question can attach to a comparison between the first quarter's reports and the latest quarter's reports in the Accident Bulletins of the Interstate Commerce Commission.

But the comparison cited is even more fundamentally defective in that it neglects to distinguish between accidents fairly subject to inquiry as to whether affected by the length of trains, and accidents that can have only a very remote relation to length of trains, if any at all. There are many trainmen injured who have nothing to do with long trains, and many of the casualties to employees who are connected with trains are in no way due to the length of the trains. Yard trainmen, for example, have nothing to do with trains on the

road, but handle long trains in yards only when such trains are in separate sections.

Therefore, it hardly needs to be argued that such comparisons of casualties prove nothing as to the increase in danger claimed to have followed the growth in number of long trains. The increase in total casualties to trainmen may just as well have been due to many causes in no way related to length of train as to causes that may possibly be so related; and the increase may just as well have occurred while there was an actual decrease in the number of casualties to those employees whose risk, it is claimed, is affected by the length of the trains.

Even though allowance be made for all these classes of employees, and the statistics limited to casualties to trainmen on the road (who, of all employees, can most reasonably be assumed to be affected by train length), still the comparison would prove nothing, because so many of the casualties even to trainmen are due to causes in no way connected with length of train, and because no separation is made between casualties to trainmen on long trains and those to trainmen on short trains. Statistical verification of the claim that long trains are more hazardous to operate than short trains would require, at the very least, that the data for casualties in connection with long trains be separated from those in connection with short trains, both classes of trains being operated under substantially the same conditions. Otherwise no comparison is possible between the risk attendant upon each class of trains in itself. But this need is not met by any statistics regularly reported by the Interstate Commerce Commission, because the distinction between long and short trains has never been observed in its compilations.

In the absence of such comprehensive data, various railways have classified the casualties on their lines according as they occurred on long or short trains, and have presented the results at hearings before legislative committees that have considered bills for limiting train length. Several of these statements are significant, though the data are so arranged that they are not readily comparable with each other. At a hearing before a committee of the General Assembly of Virginia on a bill proposing to limit all freight trains to 50 cars, N. D. Maher, vice-president of the Norfolk & Western, presented a statement for that road covering a period of two years showing the number of trains of over and under 50 cars and the

(Norfolk & Western.)

Class of trains.	Number of trains.	Per cent of total.	Number killed.	Per cent of total.	Number injured.	Per cent of total.
Trains of more than 50 cars...........	16,712	35	9	8.6	195	21.5
Trains of 50 cars or less	31,112	65	96	91.4	714	78.5

It appears from this comparison that, while there were more than one-half as many trains of over 50 cars as of trains of 50 cars or less, including passenger trains, the number of fatalities in connection with the long trains was less than one-tenth of the number in connection with the short trains, and of injuries slightly more than one-fourth. This discloses in a general way that the casualties on long trains were relatively fewer than on short trains. By how much fewer is more forcefully and definitely apparent when it is stated that, *for an equal number* of long and short trains, the number of persons killed in connection with long trains on the Norfolk & Western was only about one-sixth of the number killed in connection with short trains, while the number injured was only one-half as many.

The data in this case are complete enough to permit casualties to passengers and employees to be considered separately and with relation to the mileage of each class of trains. The results can also be distinguished as between the passenger and freight service. Eliminating from the calculation the numbers of casualties in connection with the movement of passenger trains and relating the remaining numbers of casualties, connected with freight service, to the mileage of the two classes of freight trains, the result is as follows:

Percentage Distribution of Freight Trains and Casualties.

(Norfolk & Western.)

Class of trains.	Mileage.	Per cent of total.	Employees.			
			Killed.	Per cent of total.	Injured.	Per cent of total.
Freight trains of more than 50 cars	4,173,027	61.3	1	6.2	179	30.5
Freight trains of 50 cars or less......	2,633,000	38.7	15	93.8	407	69.5

Class of trains.	Passengers.			
	Killed.	Per cent of total.	Injured.	Per cent of total.
Freight trains of more than 50 cars.	8	13.3	16	9.6
Freight trains of 50 cars or less..	52	86.7	151	90.4

In this comparison it appears that, though the mileage of freight trains of more than 50 cars was 61 per cent of the entire mileage of freight trains, the number of fatalities to employees in connection with these trains was only 6.2 per cent of the total number, and fatalities to passengers only 13.3 per cent of the total. Put in more definite terms, the data show that, *for an equal number of miles run* by long and short trains, the number of employees killed in connection with long freight trains was less than 5 per cent of the number killed in connection with short trains, while the number injured was only 28 per cent.

During a hearing before a committee of the Virginia Assembly, George P. Johnson, then general manager of the Chesapeake & Ohio, presented a statement relating to that road and covering a service of 4,896,326 train-miles for the year ending June 30, 1913, showing the relative numbers of casualties resulting from the operation of trains of more than 50 cars and of trains of 50 cars or less, as follows:

Percentage Distribution of Trains and Casualties.

(Chesapeake & Ohio.)

Class of trains.	Number of trains.	Per cent of total.	Number killed.	Per cent of total.	Number injured.	Per cent of total.
Trains of more than 50 cars.......... ...	12,073	48	4	11.4	18	9.9
Trains of 50 cars or less..............	13,099	52	31	88.6	163	90.1

This statement shows that 12,073 trains, or 48 per cent of the whole number operated, consisted of more than 50 cars, and 13,099, or 52 per cent, consisted of 50 cars or less, including passenger trains. While the number of long and short trains was thus nearly equal, the number of fatalities in connection with the long trains was only one-eighth of the number in connection with short trains, and the number of injuries less than one-ninth as great.

A summary has been made by the railways operating in Illinois showing for the year 1913 the number of employees killed or seriously injured on all trains run in that state by 23 roads. These

are subdivided to show the relation of numbers of casualties occurring in connection with the operation of trains of over 50 cars and trains of 50 cars or less. The data in detail are shown in the accompanying table:

Percentage Distribution of Trains and Casualties.

(Illinois Railways, 1913.)

Class of trains.	Number of trains.	Per cent of total.	Number killed.	Per cent of total.	Number injured.	Per cent of total.
Trains of more than 50 cars....	236,702	36	23	34.8	46	23.6
Trains of 50 cars or less..............	413,510	64	43	65.2	149	76.4

Here again, though the number of trains of more than 50 cars was 57 per cent as great as the number of trains of 50 cars or less, the number of fatalities in connection with the long trains was only 53 per cent as great as in connection with the short trains, and the number of injuries less than one-third as great. Or, put differently, for the same number of trains of each class, the number killed in connection with long trains was only about nine-tenths of the number killed in connection with short trains, while the number injured was only about one-half.

It may be argued that statistics of this character are not conclusive because of the difference in the character of the services performed by the two classes of trains. Reference is made to the fact that short trains include all local and way service trains in connection with which the service performed by trainmen includes sources of risk not found in the same degree in the through service performed by long trains. But if, as this argument concludes, long trains are used in a class of service in which, owing to its character, the risk of accident is relatively less, it follows that this particular argument gives relatively little or no ground for legislation to reduce the length of the trains used in this service.

Furthermore, the fact that there are elements in the character of the service ordinarily performed by short trains that render their

operation more liable to produce casualties, it is explained by the opponents of train-limit legislation, would argue for a possible increase in casualties if short trains were substituted for long ones. The long train ordinarily moves at a regular rate of speed, which is slower than the speeds often attained by short trains. It ordinarily makes fewer stops, and therefore incurs less risk of accidents in starting and stopping. If train length were restricted as proposed, the shortening of trains would necessarily increase those risks of accident which arise from the operation of relatively short trains at higher rates of speed.

Analysis of the Causes of Accidents, with Respect to the Effect of Long Trains.

That long trains do not tend to increase the risk of accidents in any material degree, if at all, is indicated, not only by the general considerations previously stated, but also by an analysis of the causes of accidents to trainmen, as assigned in the statistics of the Interstate Commerce Commission. The causes of accidents to trainmen, as reported by the Commission, fall into fifteen principal classes. Casualties classified according to cause, with sub-classes in the case of such main classes as could, by any possibility, be affected by the length of trains, are presented in Table V following, which applies to the fiscal year ended June 30, 1915. In the table, those immediate causes are italicized which may be reasonably considered as having been themselves due to length of train in more than rare instances. Casualties to trainmen, only, are given because they are more likely to be influenced by the length of trains than are accidents to any other class of persons. In the case of collisions and derailments, the Commission does not classify the casualties in detail according to causes.

TABLE V.

Causes of Casualties to Trainmen.

Year Ended June 30, 1915.

Cause.	Number of accidents.	Number of casualties to trainmen. Killed.	Injured.
1. Collisions	3,538	60	1,199
a. Rear[1] (p. 30)[2]	435	......	......
b. Butting[1] (p. 30)	282	......	......
c. Trains separating (p. 30)	*303*	......	......
d. Miscellaneous (p. 30)	2,518	......	......
2. Derailments	6,849	114	1,174
a. Defects of roadway (p. 32)	1,507	......	......
b. Defects of equipment (p. 32)	3,416	......	......
(1) Broken or burst wheel	335	......	......
(2) Broken flange	346	......	......
(3) Loose wheel	100	......	......
(4) Miscellaneous wheel defects	86	......	......
(5) Broken or defective axle or journal	367	......	......
(6) *Broken or defective brake rigging*	*390*	......	......
(7) *Broken or defective draft gear*	*280*	......	......
(8) Broken or defective side bearings	141	......	......
(9) Broken arch bar	222	......	......
(10) Rigid trucks	177	......	......
(11) *Failure of power brake apparatus, hose, etc.*	*353*	......	......
(12) *Failure of couplers*	*219*	......	......
(13) Miscellaneous causes	400	......	......
c. Negligence of trainmen, signalmen, etc. (p. 30)	297	......	......
d. Unforeseen obstruction of track, etc. (p. 30)	244	......	......
e. Malicious obstruction of track, etc. (p. 30)	70	......	......
f. Miscellaneous causes (p. 30)	1,315	......	......
3. Accidents to trains, cars or engines, except 1, 2 and 4 (p. 24)	......	4	203
4. Bursting of, or defects in, locomotive boilers, etc. (p. 24)	......	13	429
5. Accidents to roadway or bridges not causing derailment, such as fires, floods, landslides, etc. (p. 24)	......	......	......

[1]Some rear-end collisions may conceivably have occurred to long trains after being forced to stop by reason of breakage due to their great length. Some rear and butting collisions may conceivably have happened because of greater delay in stopping or starting trains of great length. But it is not believed, as a practical matter, that such accidents could have been numerous enough to deserve recognition in this table.

[2]Page numbers refer to I. C. C. Accident Bulletin, No. 56 (1915).

Cause.	Number of accidents.	Number of casualties to trainmen. Killed.	Injured.
6. Coupling or uncoupling cars (exclusive of accidents with air or steam hose) (p. 33)	......	88	1,949
a. Adjusting coupler with foot..	......	......	176
b. Adjusting coupler, cars accidentally started	......	4	60
c. Careless manipulation of uncoupling lever	......	......	39
d. Cars not equipped with automatic coupler	......	......	2
e. Coupler broken, using link and pin or chain	......	*5*	*35*
f. Coupling damaged cars	......	*2*	*43*
g. Coupling with chain or other emergency appliance on curve too sharp for automatic coupling	......	......	16
h. Coupling with chain or other emergency appliance because of uneven track	......	......	......
i. Coupling or uncoupling safety chain	......	2	28
j. Fingers or hand caught between uncoupling lever and body of car	......	......	309
k. Uncoupling without using lever (unnecessary)	......	......	38
l. Uncoupling without using lever (lever out of order).	......	4	107
m. Foot caught in frog, switch, or guard rail	......	4	22
n. Opening or closing knuckle when cars were near together, miscalculated speed.	......	15	160
o. Opening knuckle when cars were near together, engine accidentally started	......	9	93
p. Opening knuckle, part of defective coupler fell on foot.	......	......	*54*
q. Opening knuckle, lost footing	......	4	68
r. Riding on car to uncouple, slipped off	......	4	45
s. Struck by object at side of track	......	1	41
t. Caught by unexpected movement of car, due to slack running in	......	*12*	*155*
u. Caught by unexpected movement of car, due to misunderstanding in giving hand signals	......	*3*	*27*
v. Uncoupling moving cars and lost footing	......	6	125

Cause.	Number of accidents.	Number of casualties to trainmen. Killed.	Injured.
w. Parts hard to move, causing delay	......	1	45
x. Went between cars unnecessarily and contrary to rule.	......	8	82
y. Hand caught between projecting load and end of next car	......	......	9
z. No witness (fatal accident)	......	4	......
aa. Other causes	......	......	112
bb. Unexplained	......	......	58
7. While doing other work about trains (not in shops or engine houses) or while attending switches (p. 35)	......	76	17,770
a. Shaking grates	......	......	704
b. Firing engine (raking fire, shoveling coal into fire, etc.)	......	......	1,831
c. Coaling engine	......	1	238
d. Taking water at water cranes	......	1	440
e. The working or action of reverse levers	......	......	542
f. Scalded by water from squirt hose	......	......	219
g. Throwing switches	......	......	838
h. Poling cars	......	......	128
i. Coupling or uncoupling air or steam hose (includes the turning of angle cocks)	......	12	412
j. *Using hand brakes*	......	*1*	*1,098*
k. Loading or unloading freight, baggage, etc.	......	1	1,463
l. Cinders in eye	......	......	1,060
m. Stepping on or stumbling over objects, stepping in holes, slipping, etc., on or at side of track	......	18	3,384
n. *Unexpected or abnormal movement of trains, cars, or engine*	......	*23*	*2,082*
o. Struck by objects on or at side of track (not fixed structures)	......	1	189
p. Struck while riding in or on trains, cars, or engines, by trains, cars or engines on adjoining track	......	4	309
q. Struck while riding in or on trains, cars, or engines, by projections from trains, cars or engines on adjoining track	......	2	102
r. Miscellaneous	......	12	2,731

Cause.	Number of accidents.	Number of casualties to trainmen. Killed.	Injured.
8. Coming in contact, while riding on cars, with overhead bridges, tunnels, or any signal apparatus, or any fixed structure above or at the side of the track (p. 24)................	......	44	1,039
9–10. Falling from, or getting on or off, cars or engines (p. 34)..	......	304	10,050
a. Fell from roof of box car by reason of—			
(1) Defect in car.........	......	1	56
(2) Ice or snow...........	......	5	81
(3) *Parting of train.......*	......	*7*	*69*
(4) *Derailment, collision, or shock due to abnormal movements of cars other than those under 3 preceding ....*	......	*25*	*630*
(5) *While setting brakes...*	......	*30*	*605*
b. Fell from—			
(6)–(7) Freight car other than box car....	......	25	345
(8) Engine or tender......	......	45	734
(9) Passenger car	......	4	68
(10) Engines, tenders, or cars (all kinds) at rest	......	5	538
(11) Miscellaneous causes..	......	33	1,064
(12) Not clearly explained.	......	73	144
(13) Slipped getting on moving trains or cars.	......	25	1,018
(14) Jumping off moving trains	......	9	2,072
(15) *Jumping from engines or cars anticipating collision, derailment, or other accident....*	......	*1*	*272*
(16) Fell from engines or cars by reason of defective handholds and sill steps	......	......	416
(17) Getting on or off moving engine	......	16	1,918
(18) Caught in frog, guard rail, or switch........	......	......	20
11. Other accidents on or around trains (p. 24)................	......	......	11
(Only one of twelve subclasses of causes appears to have any possibility of connection with train-lengths, viz: "Unexpected or abnormal movement of trains, cars, or engines" (p. 35).			

Cause.	Number of accidents.	Number of casulaties to trainmen. Killed.	Injured.
12. Being struck or run over by engines or cars at stations or yards (p. 24)...............	......	136	387
13. Being struck or run over by engines or cars at highway grade crossings (p. 24).............	......	......	......
14. Being struck or run over by engines or cars at other places (p. 24)	......	42	38
15. Other causes (p. 24)............	......	3	52

To show the number and percentage of casualties from those causes which may, in some instances, have been a result of length of trains, the data in the foregoing table are summarized in Table VI as follows:

TABLE VI.

SUMMARY OF CAUSES OF CASUALTIES.

Year Ended June 30, 1915.

Causes.	Number of accidents.	Number of casualties to trainmen.	
		Killed.	Injured.
Total casualties from causes other than collisions and derailments..................	......	710	31,928
Total casualties from accidents, other than collisions and derailments, of which *some* might have been due to length of trains.	......	109	5,070
Per cent such casualties were of all casualties from causes other than collisions and derailments..........	......	15.4	15.9
Total collisions and derailments..........	10,387	....	....
Total from causes, of which *some* might have been due to length of trains......	1,545	....	....
Per cent such accidents were of all collisions and derailments..........	14.9	....	....
Total casualties from collisions and derailments	......	174	2,373

It appears, then, that of the total number of collisions and derailments in 1915, only 1,545, or 15 per cent, might conceivably have been due in some cases to the length of the trains. But the actual number of such accidents assignable, on any reasonable theory, to

the length of trains can be only a fraction of this number, for not all of these collisions and derailments happened to long trains, because long trains constituted only a small portion of all trains. Most trains are either passenger trains or short freight trains. The average number of cars per freight train in 1914 was only 34.3, showing a large majority of trains to have had less than 50 cars,[1] the usual arbitrary division point between long and short trains. Further, it is highly improbable that more than a part of such long trains as suffered collisions or derailments did so by reason of any cause due to their length. It is therefore not easy to see how length of trains could have been a determining cause of collisions or derailments in any but a very small percentage of the total cases.

Considering casualties to trainmen from causes other than collisions and derailments, it appears that the total casualties from these other causes that could possibly, on any hypothesis, have been affected by the length of trains, were 109 killed and 5,070 injured, or 15.4 and 15.9 per cent, respectively, of all the casualties from such causes. As a matter of fact, however, these causes also operate independently of the length of trains; they have many more occasions to operate in connection with the much more numerous short trains; and the number of casualties from these causes which conceivably might have been due to long trains, if any at all, must be much larger than the number that actually were due to them.

When the general arguments offered to support the claim that long trains, considered as operating units, augment accidents are thus examined in the light of an analysis of the causes of accidents, the potential influence of long trains on the number of casualties is seen to be, at most, only a negligible matter.

The Human Factor in Accidents.

It appears from other evidence that a large percentage of accidents to trains is due to error or failure on the part of employees. From this it is argued that an increase in the number of trains, and

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[1] If all mathematical possibilities be considered, the fact that the average of a number of items is less than some stated amount does not necessarily show that the majority of all the items are less than that amount. But, in view of the high probability that the number of trains within successively lengthened limits does not uniformly increase as rapidly as those limits, the statement in the text can hardly be questioned.

therefore, in the number of employees, beyond what experience has shown to be necessary for the movement of a given traffic, would be attended by an increase in accidents to trains as well as to employees. During the 13 years, 1902 to 1915, the Interstate Commerce Commission investigated directly through its own agents 1,635 train accidents which were responsible for the death of 4,062 persons, or about one-third the total number killed in train accidents during this period, and for the injury of 23,981 persons, or over one-eighth of the total number injured in train accidents. The Commission found that 1,150 of these accidents were due to negligence, mistakes or other failures of employees, 240 to mechanical defects of track, equipment, signal system or air-brake apparatus, and the remainder to weather conditions, outside interference, parting of trains, miscellaneous and unknown causes. Of the whole number investigated, therefore, 70 per cent were due to error or failure on the part of the personal element concerned in train operation. Only 152 of the accidents, or less than 10 per cent of the total, could reasonably be connected with the length of trains, namely, 110 cases of defective or weakened equipment (which may or may not have been due to train length), 31 cases of air-brake failure (which again may not have been due to train length), and 11 cases of train-parting. These 152 accidents represent virtually all that could reasonably be attributed to a large number of cars per train. That this is the case becomes even clearer when it is noted that the 1,635 accidents include those in which passenger as well as freight trains were involved.

Table VII, following, gives in detail the causes to which these accidents were attributed by the Commission:

TABLE VII.

CAUSES OF PRINCIPAL TRAIN ACCIDENTS ON RAILWAYS OF UNITED STATES, FISCAL YEARS 1902 TO 1915, INCLUSIVE.*

	Number.	
Fault of train crew:		
Disobedience of rules or orders	83	
Misread orders	70	
Excessive speed	154	
Carelessness	114	
Failure to heed signal	80	
Ran past meeting point	39	
Forgetfulness	49	
Asleep	40	
Failure to follow schedule	35	
Intoxication	5	
Failure to flag	74	
Improper flagging	40	
Failure to set brakes	41	
Other errors	7	
Total		831
Fault of dispatchers, operators, etc.:		
Wrong orders	93	
Failure to deliver orders	73	
Switch misplaced	65	
Wrong signal	62	
Other errors	4	
Total		297
Fault of other employees		22
Mechanical defects:		
Defective or weakened track	95	
Defective or weakened equipment	110	
Failure of air-brakes	31	
Failure of block signals	4	
Total		240
Hostile weather conditions		70
Malicious interference with track or equipment		46
Parting of trains		11
Miscellaneous causes		39
Causes uncertain or unknown		79
Total		1,635

* Compiled from Quarterly Accident Bulletins, Interstate Commerce Commission, 1902-1915.

Recapitulation.

The results of the foregoing review of the claim that long trains are more hazardous operating units than short trains may now be summarized.

It has been shown how comparatively few are the occasions in through freight service when length of train may be a source of *additional* risk; also how far even this limited additional risk is remediable, and is in course of being remedied, by the use of care and by improvements in equipment. From this it appears that the most in the way of irremediable risk that can fairly be chargeable to length of train is far too small, in view of other more consequential sources of risk, to be singled out for special and drastic treatment.

Further, an analysis of the available comparative casualty statistics for long and short trains, while disclosing that the statistics are not adequate to disprove the claim that long trains are more hazardous to operate than short ones would be in the same service, nevertheless shows the data to be in entire agreement with a denial of that claim. It further shows that the casualty risk attendant upon long trains is a noticeably smaller matter of concern than the casualty risk attendant upon short trains. Of this less amount of risk in connection with long trains, the part that is especially due to the greater length of such trains, whatever it may be, has been shown by the analysis of the general arguments to be at most a relatively small part. Much more, then, considering the general arguments and these statistics together, must the hazard that can be assignable to the length of such trains be of relatively small concern.

This conclusion was corroborated by a detailed consideration of the nature and possible relation to train length of each of the various causes of accidents or casualties. This showed that the accidents or casualties from all causes that might, on any reasonable explanation, be considered as sometimes due to length of train amount, at the very most, to but 15 or 20 per cent of all accidents or casualties. Account was then taken of the fact that these causes operate on short trains, as well as long ones, and even on long trains operate many times quite independently of the length of train. Allowance for these facts shows that the percentage of casualties actually at-

tributable to the length of trains must, in fact, be much smaller than the above percentage.

Finally, the dominating influence of the human factor, as shown by the proportion of casualties attributable to carelessness, negligence, or other failures of employees, shows that of all accidents or casualties from causes that *might* conceivably have been due to length of train, and therefore avoidable by reducing train length, only a part could have been actually due to that cause, and so have been prevented if trains had all been short ones.

The proposition, then, that long trains are more hazardous units to operate than short trains, fails to find a significant amount of support in either the general considerations or the available specific statistical data that bear upon it. Whatever special risk there may be, not otherwise remediable, is of such minor importance that the limitation of train length is seen to be a remedy entirely out of proportion to the actual diminution of risk that would be obtained thereby, if indeed any at all would follow.

THE EFFECT OF INCREASED TRAIN DENSITY UPON THE RISK OF ACCIDENT.

Why Increased Density Tends to Increase Accidents.

The arguments for and against train-limit legislation stated in the foregoing section have related solely to the relative safety of long and short trains considered as separate units. But such arguments are not conclusive, because they fail to take account of the more inclusive transportation problem involved. Even if it could be proved that there is less danger of accident in connection with the operation of one train of 50 cars than in connection with the operation of one train of 75 cars, this would not in itself prove that trains should be limited to 50 cars.

It is obvious that if the length of freight trains is limited by law, the freight that is now carried in that portion of trains that would be in excess of the limit will have to be otherwise provided for. It could not to any appreciable extent be provided for by trains that are now shorter than the maximum proposed to be prescribed. Many of the shorter trains are those that move in a direction that is for the time being opposite to the principal flow of traffic. They must be run with regularity regardless of the amount of business available. Many others are operated in a service in which the higher rate of speed possible with short trains is an element of efficiency. Classification of trains is essential to the expedited movement of high-class merchandise, livestock, and perishable commodities. Ordinarily no part of a possible long train can be left for attachment to a shorter train whose assigned service is of a different character. Classification enables the dispatcher to give certain trains the individual movement required by the nature of their service. Otherwise the movement of certain commodities would be dangerously delayed and the movement of others unnecessarily accelerated; both to the detriment of efficiency of service. In only a small percentage of cases could the excess cars, under a limit fixed in disregard of economic conditions of service, be cared for otherwise than by an increase in the number of trains. A result, then, of a limitation of train length would be an increase in the number of trains beyond what would otherwise be necessary.

But an increase in the number of trains involves other important considerations in the matter of safety. Suppose there are 150 cars to be moved in each direction. There enters here the question of the relative safety of operating two trains of 75 cars in each direction or three trains of 50 cars in each direction. In the first case there will be four meeting points; in the second, nine. In other words, in the first case there are four chances of butting collisions in handling the given number of cars; in the latter case, there are nine chances. Of course, strictly speaking, when trains are numerous, each one does not meet all the others, because some will reach their terminal before others have started. But it is obvious that the chances of collision increase much more rapidly than the number of trains.

A suggestion of the classes of risks other than of collisions that would be increased by an increase in number of trains is given in an illustration furnished by M. W. Potter, president of the Carolina, Clinchfield & Ohio, at a hearing before a committee of the General Assembly of Virginia. He says: "Suppose you have 48,000 tons you want to move over a section in a day. You may move that with sixteen 3,000-ton trains or eight 6,000-ton trains, four going each way. If you move that business in eight 3,000-ton trains each way, or 16 trains in all, you would have 64 meeting points in handling 48,000 tons. If you move that same tonnage in eight trains, four trains each way, you would have only 16 meeting points. As you increase the number of meetings for a given tonnage you increase the complexity of operation and the danger of accidents all along the line. Sixty-four meetings, instead of 16, means four times the danger in transmitting orders and giving signals; four times the danger of derailments in going into and out of sidings; four times the stops; four times the application of brakes; four times the sudden strain, wear and tear; four times the danger of congestion and liability of collision." This simple illustration is based on the assumption that each train would meet every other train. Even though this does not happen in actual practice, it is plain that all the risks enumerated would be increased more than in proportion to the increase in the number of trains.

Another aspect of the increase in risk attendant upon increase in train density relates to grade crossing accidents. Accidents at grade crossings obviously bear a close relation to the number of

trains, as well as the number of persons using the crossing. During the twelve months ended June 30, 1915, 1,086 persons were killed and 2,981 persons injured at grade crossings. The great majority of these persons, or 997 of those killed and 2,898 of those injured, were neither railway employees nor trespassers; that is, they were presumably persons who were utilizing the crossings in the course of their usual activities. The more trains that are run, the more chances there will be of injury to persons at highway crossings.

In support of their claim that a limit upon train length would cause an increase in the number of trains, railway men point to the fact that the increase in the *length* of trains has restricted the increase in the *number* of trains. This is strikingly shown by the statistics of the Interstate Commerce Commission. The number of tons of freight carried one mile in the United States in 1914 was nearly four times as great as in 1894, and from 1904 to 1914 the increase was 65 per cent. *Density of freight business,* or ton-miles per mile of line, increased 36 per cent during the same ten-year period. On the other hand, *freight train* density—which expresses the degree to which the railway is crowded with freight trains, and is measured by the average number of freight trains run over each mile of line per year—*decreased* 3.8 per cent.

If it had not been for the increase in trainload, largely a result of increase in length of train, this growth of traffic would have caused a corresponding increase in train density. It follows that if the length of trains be now limited, considerable increase in number of trains would be required to handle the volume of business now carried by the railways, while increase in all the hazards of operation would follow such an increase in train density.

Statistical Evidence of the Relation of Accidents and Casualties to Train Density.

Even if it were admissible that the absolute number of fatalities and injuries to any or all classes of persons resulting from railway operation showed an increase from year to year, it would not necessarily prove that the character of railway operation is becoming increasingly dangerous. It has been shown in a preceding section that the public service performed by railways has increased greatly

within the last ten years. The tonnage of freight handled, the number of passengers carried, and the number of employees in railway service have greatly increased. It has been considered proper, therefore, in opposing attempts to secure train-limit legislation to introduce statistics tending to show such relation as may have existed in previous years between the number of casualties resulting from railway operation and train density, which is the important operating element affected by train limitation. There have also been made comparisons designed to show that the increase in volume of public service performed by railways in recent years has not been accompanied by corresponding increases in number of casualties resulting from train operation. The pertinency of this latter comparison rests upon the showing that the increase in volume of public service performed has been brought about by the use of long freight trains without a corresponding increase in train density.

The claim of railway men that the increase in train density which would follow a limitation of train length would cause an increase in casualties is amply proven from the relation between train density and accidents or casualties in the past.

While the increase in the number of trains run per mile of line is shown to have been very small in relation to the increase in the amount of freight handled, there have been years when there were sharp increases or decreases in the total number of freight trains run, due to fluctuations in the total amount of freight to be handled. These changes have caused corresponding increases and decreases in freight-train density. The effect on railway accidents produced by these increases in the number of trains run and the resultant increases in freight-train density is doubtless similar to that which would be produced by the increase in the number of trains that would be necessitated by legislation limiting and reducing the length of trains.

Considering the causes and occasions of various kinds of accidents and casualties, it would be expected that those most directly affected by train density would be such accidents as collisions, derailments and other accidents to trains, and such casualties, resulting from these accidents, as happen to persons employed on trains or riding on them, such as trainmen and passengers. Without doubt there are other accidents than those named and casualties to other persons than those named, that are affected by the degree of train density.

But they are at the same time subject to so many other concurrent influences that the statistics of all such accidents and casualties do not show a regular dependence on the amount of the train density. However, the accidents and casualties first named are found, by statistical tests, to vary with train density in such a degree of uniformity as to corroborate the conclusion that the rise and fall of train density must be accompanied by a rise and fall in the number of these accidents and casualties. Therefore, the claim of railway men that the limitation of train length will, by increasing train density to a greater amount than otherwise, cause a greater number of accidents and casualties than otherwise would occur, is fully supported by the statistics.

The data that prove that claim are here given in full. The statistical methods, however, by which the significance of the statistics is disclosed are rather technical to describe simply, and will be found in an appendix by those who wish to check them.

The train density considered in these tables is that of all trains. The advocates of train-limit legislation propose to limit the length of freight trains only. But it is the total number of trains of all kinds, and not merely of freight trains upon a given section of track, that affects the liability to accident. The effect of an increase in freight trains would thus be felt as an increase in all train density. In addition to this logical reason for considering the density of all trains is the practical one that the accident statistics compiled by the Interstate Commerce Commission include accidents resulting from the movement of all classes of trains. Therefore, the comparisons in the following tables are made on a basis to include all trains. For statistical purposes train service is represented by train-miles. The unit of freight-train service is the freight-train run one mile and the unit of passenger-train service is the passenger-train run one mile. Train density indicates the average number of these trains run one mile per mile of line per year. The relation of fluctuations in the total number of trains run one mile, and in freight trains run one mile, to the total number of collisions, derailments, and to casualties resulting therefrom, is instructive.

Relation to Train Density of Collisions and Derailments.

In Table VIII are shown, in parallel columns, year by year from 1903 to 1914, the total train-mileage, density of all trains, the number of collisions and the number of derailments. Although statistics are available for 1902, they are omitted from this and the following tables because the data on accidents are admittedly incomplete. The increases from one year to another are indicated by "I" and the decreases by "D."

TABLE VIII.

RELATION TO TRAIN DENSITY OF COLLISIONS AND DERAILMENTS.*

Year.	Total train mileage.	Train density.	Collisions.	Derailments.
1903......	982,946,284	4,848	6,167	4,476
1904......	1,007,529,452 I	4,826 D	6,436 I	4,855 I
1905......	1,038,441,430 I	4,839 I	6,224 D	5,371 I
1906......	1,105,877,091 I	5,035 I	7,194 I	6,261 I
1907......	1,171,922,997 I	5,211 I	8,026 I	7,432 I
1908......	1,129,149,453 D	4,931 D	6,363 D	6,671 D
1909......	1,112,452,351 D	4,776 D	4,411 D	5,259 D
1910......	1,221,852,647 I	5,131 I	5,861 I	5,918 I
1911......	1,237,500,138 I	5,081 D	5,605 D	6,260 I
1912......	1,236,758,715 D	4,986 D	5,483 D	8,215 I
1913......	1,280,931,735 I	5,090 I	6,477 I	9,049 I
1914......	1,251,791,798 D	4,909 D	5,241 D	8,565 D

*Accident statistics are from Interstate Commerce Commission Accident Bulletins. Train-mile and train-density statistics are compiled from the Interstate Commerce Commission's annual Statistics of Railways in the United States.

This table shows that, during the twelve years covered, nearly every increase or decrease in the number of train miles run and in train density was accompanied by a corresponding increase or decrease in the number of collisions and of derailments.

It is recognized that agreement merely in the upward or downward direction of change is entirely inadequate, by itself, to prove that accidents and casualties depend on train density. But this agreement has been tested by more accurate statistical methods which are described in the appendix and has been found to be a real and not merely an apparent agreement. Consequently the simpler and more obvious method of presentation, in which corresponding changes in movement upward or downward are emphasized, has been followed in the text.

The statistics thus support the claim of railway men that the increase in the number of trains that would be required if train length is restricted will surely cause an increase in the number of collisions and derailments, because it will increase the occasions or opportunities for such accidents.

It would be perfectly reasonable to expect, also, that an increase in train density would cause an increase in other accidents to trains besides collisions and derailments, as claimed in the quotation already given on page 40. But this cannot be tested statistically, because the Interstate Commerce Commission has not reported the number of such accidents for enough years to afford a representative period.

The available statistics of train accidents since 1911 show that the relationship for all train accidents closely follows that for collisions and derailments separately. This would be expected, for collisions and derailments form by far the greater proportion of all train accidents (ninety per cent in 1915), and naturally determine the trend of all such accidents.

Relation to Train Density of Casualties to Trainmen and Passengers.

Turning now to a consideration of casualties to persons, it would seem to follow from the effect of train density on accidents that the casualties, also, experienced in those accidents would increase with an increase of train density. And this deduction is supported by the statistics. In Tables IX, X, XI, XII, XIII, and XIV, are taken up the relationship between train-mileage and train density and casualties to passengers and to trainmen, respectively, resulting from the movement of trains.

In each of these tables is given a statement of total train-miles and of train density for each of the years 1903 or 1904 to 1914, inclusive. The items are marked with "I" or "D," showing whether the record for each year indicates an increase or decrease in train-mileage or train density as compared with the preceding year. In comparison with these data are presented in separate columns the number of killed and of injured in the corresponding year. These items are also marked with "I" or "D," indicating increase or decrease in number of killed or injured compared with the preceding year.

As in the case of collisions and derailments, the relation of these casualties to train density has been proven by statistical tests. But, for simplicity in presentation, only the general agreement in increases and decreases is shown in these tables. In view of the many directions in which it has been sought, especially in recent years, to reduce the hazard of train operation, it was not to be expected that in every instance in which comparison was made there would be shown a complete correspondence of increase or decrease. But throughout most of the years there can be seen a rather complete agreement of increases and decreases when the data for any year are followed through the various columns in any of the tables.

Relation to Train Density of Casualties to Trainmen on the Road.

In the following three tables the variations from year to year in the number of casualties to trainmen on the road are compared with the variations from year to year in the train density. The statistics begin with 1904 because that was the first year when casualties to trainmen on the road were shown separately from casualties to all trainmen, including those in yard service. In Table IX are compared the casualties from collisions, and in Table X, those from derailments.

TABLE IX.

RELATION TO TRAIN DENSITY OF CASUALTIES TO TRAINMEN ON THE ROAD, OCCURRING IN COLLISIONS.*

			Casualties to trainmen.		
Year.	Total train mileage.	Train density.	Killed.	Injured.	Total casualties.
1904....	1,007,529,452	4,826	267	2,077	2,344
1905....	1,038,441,430 I	4,839 I	259 D	1,922 D	2,181 D
1906....	1,105,877,091 I	5,035 I	331 I	2,348 I	2,679 I
1907....	1,171,922,997 I	5,211 I	364 I	2,702 I	3,066 I
1908....	1,129,149,453 D	4,931 D	191 D	1,832 D	2,023 D
1909....	1,112,452,351 D	4,776 D	145 D	1,266 D	1,411 D
1910....	1,221,852,647 I	5,131 I	216 I	1,765 I	1,981 I
1911....	1,237,500,138 I	5,081 D	184 D	1,634 D	1,818 D
1912....	1,236,758,715 D	4,986 D	186 I	1,740 I	1,926 I
1913....	1,280,931,735 I	5,090 I	162 D	1,824 I	1,986 I
1914....	1,251,791,798 D	4,909 D	128 D	1,031 D	1,159 D

*Accident statistics are from Interstate Commerce Commission Accident Bulletins. Train-mile and train-density statistics are compiled from the Interstate Commerce Commission's annual Statistics of Railways in the United States.

TABLE X.

RELATION TO TRAIN DENSITY OF CASUALTIES TO TRAINMEN ON THE ROAD, OCCURRING IN DERAILMENTS.*

Year.	Total train mileage.	Train density.	Casualties to trainmen. Killed.	Injured.	Total casualties.
1904....	1,007,529,452	4,826	229	1,078	1,307
1905....	1,038,441,430 I	4,839 I	223 D	1,316 I	1,539 I
1906....	1,105,877,091 I	5,035 I	220 D	1,385 I	1,605 I
1907....	1,171,922,997 I	5,211 I	259 I	1,786 I	2,045 I
1908....	1,129,149,453 D	4,931 D	203 D	1,412 D	1,615 D
1909....	1,112,452,351 D	4,776 D	171 D	996 D	1,167 D
1910....	1,221,852,647 I	5,131 I	188 I	1,272 I	1,460 I
1911....	1,237,500,138 I	5,081 D	184 D	1,211 D	1,395 D
1912....	1,236,758,715 D	4,986 D	191 I	1,610 I	1,801 I
1913....	1,280,931,735 I	5,090 I	169 D	1,418 D	1,587 D
1914....	1,251,791,798 D	4,909 D	159 D	1,221 D	1,380 D

*Accident statistics are from Interstate Commerce Commission Accident Bulletins. Train-mile and train-density statistics are compiled from the Interstate Commerce Commission's annual Statistics of Railways in the United States.

The correspondence between casualties and train density, indicated in the foregoing tables and proven by more careful statistical analysis, is sufficiently close to substantiate the deductive claim of railway men that the increase in train density, which would follow a restriction of train length, will be sure to cause more casualties to trainmen than would otherwise occur.

The statistics of Tables IX and X are extended in Table XI following, to cover casualties to trainmen in all train accidents. This table shows the relation between increases and decreases in train mileage and train density and casualties to trainmen in train accidents, 1904 to 1914. While the total of train accidents includes some accidents not due to collisions or derailments, such as locomotive-boiler explosions, yet the correspondence between the showing of Tables IX and X, on the one hand, and Table XI, on the other, is very close. This is natural, considering the fact already noted, that collisions and derailments constitute a large proportion of all train accidents.

TABLE XI.

RELATION TO TRAIN DENSITY OF CASUALTIES TO TRAINMEN ON THE ROAD, ALL TRAIN ACCIDENTS.*

Year.	Total train mileage.	Train density.	Casualties to trainmen. Killed.	Injured.	Total casualties.
1904....	1,007,529,452	4,826	558	4,135	4,693
1905....	1,038,441,430 I	4,839 I	533 D	4,210 I	4,743 I
1906....	1,105,877,091 I	5,035 I	612 I	4,769 I	5,381 I
1907....	1,171,922,997 I	5,211 I	707 I	5,540 I	6,247 I
1908....	1,129,149,453 D	4,931 D	453 D	4,138 D	4,591 D
1909....	1,112,452,351 D	4,776 D	352 D	2,989 D	3,341 D
1910....	1,221,852,647 I	5,131 I	479 I	4,123 I	4,602 I
1911....	1,237,500,138 I	5,081 D	428 D	4,048 D	4,476 D
1912....	1,236,758,715 D	4,986 D	407 D	4,367 I	4,774 I
1913....	1,280,931,735 I	5,090 I	369 D	4,072 D	4,441 D
1914....	1,251,791,798 D	4,909 D	296 D	2,721 D	3,017 D

*Accident statistics are from Interstate Commerce Commission Accident Bulletins. Train-mile and train-density statistics are compiled from the Interstate Commerce Commission's annual Statistics of Railways in the United States.

Relation to Train Density of Casualties to Passengers.

The other class of persons who may be expected to be much affected by an increase in train density is that of passengers. The more freight trains there are on the road, the more chances of casualties to passengers from collisions, derailments and other accidents occasioned by a more densely crowded condition of the tracks. In Table XII following, the variations in the number of casualties to passengers in collisions are shown in comparison with the variations in the train density, from 1903 to 1914. In Table XIII the variations in casualties from derailments are compared with the variations in train density.

TABLE XII.

RELATION TO TRAIN DENSITY OF CASUALTIES TO PASSENGERS, OCCURRING IN COLLISIONS.*

Year.	Total train mileage.	Train density.	Casualties to passengers. Killed.	Injured.	Total casualties.
1903....	982,946,284	4,848	152	3,200	3,352
1904....	1,007,529,452 I	4,826 D	166 I	3,383 I	3,549 I
1905....	1,038,441,430 I	4,839 I	198 I	3,493 I	3,691 I
1906....	1,105,877,091 I	5,035 I	120 D	4,005 I	4,125 I
1907....	1,171,922,997 I	5,211 I	209 I	4,733 I	4,942 I
1908....	1,129,149,453 D	4,931 D	111 D	4,284 D	4,395 D
1909....	1,112,452,351 D	4,776 D	94 D	3,033 D	3,127 D
1910....	1,221,852,647 I	5,131 I	78 D	4,428 I	4,506 I
1911....	1,237,500,138 I	5,081 D	93 I	3,672 D	3,765 D
1912....	1,236,758,715 D	4,986 D	66 D	4,716 I	4,782 I
1913....	1,280,931,735 I	5,090 I	141 I	4,470 D	4,611 D
1914....	1,251,791,798 D	4,909 D	38 D	3,426 D	3,464 D

TABLE XIII.

RELATION TO TRAIN DENSITY OF CASUALTIES TO PASSENGERS, OCCURRING IN DERAILMENTS.*

Year.	Total train mileage.	Train density.	Casualties to passengers. Killed.	Injured.	Total casualties.
1903....	982,946,284	4,848	60	1,645	1,705
1904....	1,007,529,452 I	4,826 D	103 I	1,422 D	1,525 D
1905....	1,038,441,430 I	4,839 I	151 I	2,891 I	3,042 I
1906....	1,105,877,091 I	5,035 I	60 D	2,656 D	2,716 D
1907....	1,171,922,997 I	5,211 I	185 I	4,184 I	4,369 I
1908....	1,129,149,453 D	4,931 D	54 D	3,057 D	3,111 D
1909....	1,112,452,351 D	4,776 D	37 D	2,717 D	2,754 D
1910....	1,221,852,647 I	5,131 I	87 I	2,946 I	3,033 I
1911....	1,237,500,138 I	5,081 D	48 D	2,884 D	2,932 D
1912....	1,236,758,715 D	4,986 D	72 I	4,541 I	4,613 I
1913....	1,280,931,735 I	5,090 I	39 D	4,076 D	4,115 D
1914....	1,251,791,798 D	4,909 D	46 I	3,512 D	3,558 D

*Accident statistics are from Interstate Commerce Commission Accident Bulletins. Train-mile and train-density statistics are compiled from the Interstate Commerce Commission's annual Statistics of Railways in the United States.

Here, again, the correspondence between casualties and train density, indicated in the foregoing tables and proven by further statistical analysis, is such as to support the claim of railway men that the increase in train density, which would be forced by imposing a restriction on the length of freight trains, will result in more casualties to passengers than would otherwise occur. The proposal to limit train length is thus a menace, not only to those employees who operate trains, but also to the traveling public, and should be considered with full recognition of this fact.

In the case of passengers, as well as of trainmen, the trend of casualties in all train accidents closely follows that of casualties in collisions and derailments. All train accidents include locomotive-boiler explosions and certain other accidents to trains, in addition to collisions and derailments. Table XIV following, gives statistics of casualties to passengers in all train accidents, 1903 to 1914.

TABLE XIV.

RELATION TO TRAIN DENSITY OF CASUALTIES TO PASSENGERS, ALL TRAIN ACCIDENTS.*

Year.	Total train mileage.	Train density.	Casualties to passengers.		
			Killed.	Injured.	Total casualties.
1903....	982,946,284	4,848	215	4,931	5,146
1904....	1,007,529,452 I	4,826 D	270 I	4,945 I	5,215 I
1905....	1,038,441,430 I	4,839 I	350 I	6,498 I	6,848 I
1906....	1,105,877,091 I	5,035 I	182 D	6,778 I	6,960 I
1907....	1,171,922,997 I	5,211 I	410 I	9,070 I	9,480 I
1908....	1,129,149,453 D	4,931 D	165 D	7,430 D	7,595 D
1909....	1,112,452,351 D	4,776 D	131 D	5,865 D	5,996 D
1910....	1,221,852,647 I	5,131 I	217 I	7,516 I	7,733 I
1911....	1,237,500,138 I	5,081 D	142 D	6,722 D	6,864 D
1912....	1,236,758,715 D	4,986 D	139 D	9,391 I	9,530 I
1913....	1,280,931,735 I	5,090 I	181 I	8,662 D	8,843 D
1914....	1,251,791,798 D	4,909 D	85 D	7,001 D	7,086 D

*Accident statistics are from Interstate Commerce Commission Accident Bulletins. Train-mile and train-density statistics are compiled from the Interstate Commerce Commission's annual Statistics of Railways in the United States.

Relation to Train Density of Other Casualties.

An increase in train density would, in all probability, tend to increase other classes of casualties than those above considered. Additional trains on the road would tend to augment somewhat the business in terminal yards and railway shops, and thus affect the

casualties from train accidents that happen to other employees than trainmen on the road. Also, it is quite probable that increased train density would swell the number of casualties sustained in connection with moving trains, but not in collisions, derailments, or other accidents to trains themselves. The more trains there are running, the more occasions there are for casualties to employees in connection with the numerous duties of operating trains, or working about yards, stations or warehouses where trains pass or move about. The more, too, are the occasions for passengers and others to be struck by passing trains in stations, and especially at highway crossings. Such casualties as these result from many other causes and occasions besides train density, so that train density alone is not responsible for a sufficiently large proportion of all such casualties to make the total from all these causes vary in very close agreement with it. However, although it is thus not possible to find, in the data that are available, any statistical support of the conclusion deduced from other than statistical considerations, the conclusion has firm ground in those considerations to sustain it.

Relation to Train Density of the Risk of Accidents and Casualties.

In all of the foregoing statistics train density has been compared only with the total number of the accidents and casualties considered. But the claim of railway men is, not merely that the *number* of accidents and casualties will increase with train density, but also that the *risk* will increase. That claim is supported by the consideration that occasions or opportunities for accidents and casualties increase *more than in proportion* to the increase in number of trains. This argument cannot be given statistical verification, although it would seem a perfectly sound deduction from the facts. The difficulties in the way of statistical verification lie partly in the lack of a satisfactory measure of risk and partly in the concurrent effect of other influences on risk besides that of train density. Yet it cannot be doubted that there is an added risk run by each trainman and each passenger when the number of trains is increased, and *vice versa*. That is to say, train-limit legislation, by making train density higher than it would otherwise be, will not only result in accidents to more trains and casualties to more persons than otherwise, but will increase the chances of each train and of each trainman and passenger meeting with disaster.

Summary of Evidence on the Effect of Train Density Upon Accidents and Casualties.

A consideration of the causes and occasions of accidents and casualties, as related to train density, and an examination of the statistics thereon, thus leave no doubt, it would seem, that the number of collisions and derailments and the number of casualties therefrom to trainmen on the road and to passengers are largely and directly affected by the density of trains upon the railways.

The same consideration of the causes and occasions of accidents and casualties leads directly to a similar conclusion with respect to many of the other train accidents, besides collisions and derailments, and of the casualties therefrom, and to many of the casualties to all employees and passengers, and even other persons, that occur in accidents connected with moving trains, but not train accidents, so called. These all appear to be either directly or indirectly influenced by the density of trains. This conclusion stands, regardless of the fact that the number and concurrent effect on such accidents and casualties of other influences than train density are so great as to prevent the statistics from revealing the relation of such accidents and casualties to train density.

Considering now that it has been shown that a limitation upon the length of freight trains would unavoidably cause an increase in the number of trains, there seems to be adequate basis for the contention that, if the length of freight trains be limited by law, train density will be greater than it otherwise need be. To the extent that train density is greater, it will cause the number of accidents and casualties to be greater than they need be. And not only the number, but also the risk of accident and casualties would be increased.

The Greater Relative Importance of Train Density in the Safety of Railway Operations.

Since that result would follow a limitation of train length, railway men are convinced that the claim of employees concerning the danger of operating long trains becomes of minor importance. For, even if it be conceded that long trains are more hazardous units of

railway operation than short trains, it appears that the safety of railway operation as a whole is chiefly determined by the much more important factors involved in train density. They contend that, whatever the shortening of trains might conceivably accomplish in reducing the risk of casualty in connection with the operation of the individual train, it would be much more than offset by the increase in risk of collision and other accidents, and of casualties therein, that would result from the increase in the number of trains operated.

It appears from the statistical comparisons presented in the foregoing that there is a close relation between train density and number of casualties to trainmen and to passengers. It is admitted by railway officials that other influences have been exerted in the direction of securing a greater degree of safety in railway operation; but since fluctuations in train density in either direction are ordinarily accompanied by changes in number of casualties, the influence of train density appears to predominate. Train density, under any given conditions, and especially so far as freight trains are concerned, will ordinarily depend upon the number of cars which it is permissible and practicable to operate as a single train. The fewer cars per train there are, the greater the train density and the more numerous in proportion are the accidents.

Decrease in Casualties in Relation to Service Performed by Railways.

There is another aspect of the argument on safety that should be noted if the matter is to be considered in its entirety. The railway business is not unlike many others, on which the public is dependent, in that loss of life and personal injury are unavoidable incidents of the operations by which its service is rendered. Since, therefore, casualties are to be expected, the only question is one of steadily reducing them in proportion to the service performed. Now that is exactly what the railways have been doing, and one of the principal means of doing it has been the use of long train units.

A summary comparison of the increases in railway traffic as a whole over a period of years, and in the numbers of casualties to employees and passengers, is presented in Table XV. The period covered is from 1905 to 1914, inclusive. Since comparisons between individual years may be objectionable on the ground

of the unrepresentative character of one or both of the years selected, the present study presents annual averages of the data for two periods of five years each—1905 to 1909 and 1910 to 1914, inclusive in each case. The comparison of the data for 1905-1909 with that for 1910-1914 indicates the general tendency of number of casualties in relation to volume of service performed by the railways. The entire period has been especially characterized by increases in the length and capacity of freight trains.

TABLE XV.

SUMMARY OF INCREASES IN RAILWAY TRAFFIC IN RELATION TO NUMBERS OF CASUALTIES.

*Comparison of Averages for Five-year Period 1905 to 1909 with Averages for Period 1910 to 1914, Inclusive.**

	Average per year 1905–1909.	Average per year 1910–1914.	Increase per cent 1905–1909 to 1910–1914.
Freight ton miles......	215,225,000,000	272,641,000,000	26.7
Freight train miles.....	585,300,000	625,633,000	6.9
Passengers one mile....	26,976,000,000	33,739,000,000	25.1
Passenger train miles..	492,030,000	581,890,000	18.3
Total freight and passenger train miles....	1,077,000,000	1,208,000,000	12.2
Number of employees..	1,502,945	1,725,842	14.8
Mileage of roads.......	226,533	249,388	10.1
Number of employees per 100 miles of line..	663	692	4.4
Number of employees:			
Killed	3,447	3,186	7.6 Dec.
Injured	54,357	55,047	1.3
Number of passengers:			
Killed	469	353	24.7 Dec.
Injured	11,917	15,047	26.3

*Computed from Statistics of Railways in the United States, Interstate Commerce Commission, and from Accident Bulletins for the years included. "Industrial Accidents" are excluded.

The comparisons show that the increases in casualties have been much smaller in proportion than the increases in the volume of railway service rendered, except in the number of passengers injured. In fact, in the last five-year period covered there were absolute decreases in fatalities to both passengers and employees, notwithstanding an increase of about 25 per cent in the average amount of passenger and freight traffic handled and of over 14 per cent in the average number of employes. In view of the sharp reduction

in number of passengers killed, part of the increase in number injured may reasonably be regarded as due to improved methods of reporting the details of unimportant casualties. The reduction in fatalities leads also to the conclusion that the severity of passenger casualties as a whole has been considerably reduced.

Summary of Evidence on Relation of Train Density to Accidents.

From this examination of the experience of railways over a period of years, there would seem to be no question that the number of collisions and derailments, and the number of casualties to passengers and trainmen in train accidents, all bear a well-marked relation to total train density.

The relation which has been demonstrated to exist between train density and casualties resulting from railway operation appears clearly to be one of cause and effect.

It appears also that notwithstanding progressive increases in volume of business and in number of employees, there has been no corresponding increase in number of casualties incident to railway operation. On the contrary, in recent years there is shown a tendency to decrease in the number of casualties in comparison with the increase in volume of railway business. Because of the increase in length of many trains, the increase in volume of business has not been accompanied by a corresponding increase in accidents and casualties.

ECONOMIC CONSIDERATIONS INVOLVED IN TRAIN-LIMIT LEGISLATION.

If it could be shown that the operation of long trains entailed increases in casualties, purely economic considerations would be forced to give way to the more important consideration of safety. But it appears from the foregoing discussion of the arguments on safety that the net effect of increase in the length of trains is not to increase the hazards of operation, but so far as is determinable has the opposite tendency. This being the case, it becomes proper and pertinent to point out briefly some economic considerations involved.

Much of Recent Railway Investment Would Be Rendered Valueless.

The tendency of transportation on both water and land always has been toward the use of larger units of operation, the main purpose being to reduce the cost per ton of rendering the service. The development of the large unit in railway operation has involved large investments of capital in forms designed solely to permit the use of larger train units. The productiveness of many of these investments would be nullified by legislation designed to arrest this form of economic advance.

Investment in Roadway and Track.—To enable them to haul longer and heavier trains railway companies have made large investments for the reduction of grades and the elimination of curvature in their main track and for the construction of long passing and yard tracks. The investment for these purposes would be rendered practically valueless by the enactment of legislation that would not permit the operation of long trains, the very purpose for which the investment was made.

Investment in Car Construction and Equipment.—Increased strength of car construction, among other things the substitution of steel for wood as a structural material, has been an essential element in increasing the capacity of the unit of transportation. Improvements in brake systems, couplings, etc., have had the purpose and effect of making the train more nearly a unit, both physically and as to control, than formerly. These features of progress in car construction and equipment have permitted an in-

crease in the number of cars hauled in a train without correspondingly increased liability to casualties resulting from failure of the car body, or of connections between cars, or of connections between cars and locomotive. Some of the principal advantages derived from the use of steel under-frames and center sills, of improved draft gear, of brake apparatus highly specialized with reference to its required service, and other features of strength in individual parts of equipment, would be greatly reduced and the increased investment in them rendered largely unproductive, if the number of cars handled in single trains should be limited as proposed.

Investment in Larger Locomotives.—The tractive power of locomotives has been greatly increased in order that a longer and heavier train may be hauled by a single locomotive. Such increases in tractive power have been obtained only at an increased cost per locomotive. The additional tractive power of these large locomotives and the additional investment made to secure it would become valueless under the proposed legislation.

Investment in Engine Terminals.—That portion of a railway's investment in roundhouses and in all such facilities as turn-tables, which has been made to adapt them to the accommodation of large locomotives, would be rendered unproductive.

Many Economies in Operating Expenses Would Be Lost.

Limitation of train length would prevent many reductions in operating expenses now being effected by means of large train-loads. In 1890 the average number of tons handled per train in the United States was 175.1. The average revenue of the railways per ton per mile was .941 cents. In some sections of the country it was as high as 1.651 cents. At the average rate per ton per mile and at the average tonnage per train in 1890, the railways received $1.65 per freight train per mile. In 1914 the average number of tons of freight hauled in a train was 451.8. The average revenue per ton per mile was .733 cents. The earnings per freight train per mile at this lower average freight rate were $3.31, or twice as great as they were at the higher average rate charged in 1890. These figures indicate clearly how the increase in the length and capacity of trains has enabled the railways to make greatly reduced rates to the shipper, pay greatly increased wages, and at the same time steadily

improve their service. Without the increase in the length and capacity of trains, either rates could not have been reduced, or wages could not have been so increased, or the railways would have been compelled to economize at the expense of service or suffer financial ruin.

Additional Investment Would Be Made Necessary.

Legislation limiting the length of freight trains would not only render valueless a great part of recent investments, but would require additional investment on the part of the railways to accommodate their operations to changed conditions.

It would necessitate an increase in the number of locomotives equal to the increased number of trains required to handle a given traffic.

The increased number of locomotives would make necessary remodeling of locomotive terminal facilities in order to provide additional stalls in roundhouses and more track room in yards proportionate to the increase in number of locomotives.

Additional tracks, sidings, switches and signal apparatus would be required in a ratio indicated approximately by the increase in number of trains that would result from limitation of train-length. If traffic were equal in both directions and at all times of the day, and if every train met every other train, meeting points, alone, of trains would increase as the square of the number of trains. Additional passing points, with trains in the same direction, but of different speed, would cause the total of both meeting and passing points to increase in even a greater ratio. And meeting and passing facilities would have to be provided accordingly. Since the actual conditions are not so uniform as that, the increase in the number of meeting and passing points might be more or less than this, but there would be a material increase.

Financial Effects of Train-limit Legislation.

When a bill to limit the length of freight trains to 50 cars was pending in the legislature of Illinois in 1915, data were compiled by 23 roads, having 8,781 of the 12,611 miles of railway in that state, showing the estimated effect that would be produced by such legis-

lation on their investment and operating expenses. These data, summarized, were as follows:

Investment made valueless:	
a. For grade reduction and heavy rail	$30,631,943
b. For siding and terminal track extensions	6,727,453
c. For heavy motive power	8,075,160
Total	$45,434,556
Increase in operating expenses per year:	
a. Increase in payroll, enginemen and trainmen	$2,266,059
b. Increase in payroll, other employees	976,141
c. Increase in cost of fuel	1,025,480
Total	$4,267,680
New capital required:	
a. For locomotives	$4,007,080
b. For passing and terminal tracks, etc.	4,138,850
c. For locomotive terminal facilities	3,955,000
Total	$12,100,930
d. For second, third, and fourth track requirements in ten years	$43,495,360

Reduced to a mileage basis, it appears from this statement that the railways of Illinois placed the amount of investment that would be rendered valueless by a limitation of the length of freight trains to 50 cars, at $5,198 per mile; increase in operating expenses per year, $488 per mile; immediate investment of new capital, $1,384 per mile; amount of new capital the investment of which would be made necessary in 10 years, $4,976 per mile. Whether similar legislation would produce proportionate effects on all the more than 250,000 miles of railway in the United States can only be conjectured.

Effect on Rates Paid by the Public.

Railways have only one source from which to derive the means for paying their fixed charges and operating expenses. This is the revenue received by them from the public for the transportation of passengers and freight. Since legislation limiting the length of trains would increase their fixed charges and operating expenses, it is clear that it would, in the long run, make the passenger and freight rates which they would have to charge the public, and would be legally entitled to charge it, higher than would otherwise be necessary.

Appendix.

Statistical Proof of the Relation to Train Density of Accidents and Casualties.

The statistical proof that train density has an important effect on the number of accidents and casualties can be briefly indicated.

The comparison with train density of the number of accidents and of casualties, as specified in the text, has been made with full recognition of the fact that other factors, as well as train density, affect the number of accidents and casualties. But, since it is not possible to eliminate these other factors entirely in order to observe the relation between train density alone and accidents and casualties, it has been necessary to compare the general trend of accidents and casualties from all causes and influences with the general trend of the single influence, train density, and make allowance in the conclusions for the probable effect of the other causes.

Most important of these other influences are the human factor and the numerous safety appliances or other improvements in conditions affecting safety, such as second and other additional tracks. As to the human factor, it is reasonable to assume that the "safety-first" movement has made employees somewhat more careful, and hence that accidents and casualties have become somewhat fewer than they would have been otherwise.

As to safety appliances, these have doubtless more and more prevented accidents as the use of such appliances has increased and their improvement has progressed. Moreover, the steady increase in second, third, and other tracks tends to reduce the chances of accident from congestion of the line with trains.

The effect of such cumulative changes in these other factors would be to reduce the total number of accidents and casualties below what it otherwise would have been by reason of the influence of train density. The actual statistics, therefore, would not reflect the effect of train density as closely as if there had been no such changes in these other conditions affecting safety. Hence the dependence of accidents and casualties on train density may be assumed to be even greater than that indicated by the statistics in the form in which they are available.

The most definite and precise method of detecting whatever relation,—or, more accurately, whatever correlation,—there may be between two series of numbers that appear to vary in agreement with each other, is a mathematical computation which gives a result that measures the degree or extent to which the two series of numbers are correlated. This result is known as the coefficient of correlation. If the two series of numbers are completely correlated, the coefficient of correlation will be 1. If they are not completely dependent, one upon the other, the coefficient of correlation will be a decimal less than 1, its amount being smaller the less the correlation between the two series of numbers. If the two series of numbers vary without any relation whatever to each other, the coefficient of correlation will be 0. Thus the coefficient of correlation is virtually a measure, in percentage, of the dependence of one series of numbers on the other.

In the present case, one of the two series of numbers to be tested is that of the train density, year by year, considered as a condition affecting the number of certain classes of accidents and casualties. The other series of numbers is that of the accidents and casualties, year by year, that are thought to depend in part upon the degree of train density. Now the numbers in this latter series are, as already noted, affected by influences other than, but concurrent with, train density. These other influences may, and doubtless usually do, change their upward and downward tendencies quite independently of the changes in train density. Therefore, the statistics that are available of accidents and casualties, being subject to these other concurrent influences also, show a dependence on train density only to the extent that it is one of the predominant influences. That is to say, the coefficient of correlation for train density and any class of accidents or casualties tends to be lower than it would be if all these other influences should remain unchanged from year to year, and the effect of train density alone on the class of accidents or casualties were thus separately tested.

Therefore, whatever the coefficient of correlation between the available statistics on accidents or casualties and those on train density, it may be assumed to be less than the true measure of the independent effect of changes in train density.

It is commonly held among statisticians that a coefficient of correlation of about .50 indicates a correlation between the statistics

under comparison sufficient to support a proposition, derived from other reasoning, that one series of statistics depends upon the other. And the higher the coefficient is above .50 the greater the evidential value of the statistics.

On the other hand, a coefficient appreciably less than .50, and especially as low as or lower than .35, is not considered as indicating a sufficient degree of correlation between the two series or groups of statistics to support an argument that either series depends on the other. And if the coefficient is as low as .25, and especially if as low as .10, the statistics cannot be considered as affording any support whatever to a postulated relationship between them. However, this does not mean that a low coefficient of correlation necessarily *disproves* the proposition. That would depend on how nearly each series of statistics represented one factor only in the problem. If either series represented more than one factor, it might well be that the relation could be shown, from other than statistical arguments, to be true for that one factor, and yet the relative weight of that factor be so small that the relation would not be reflected in the statistics.

Turning now to the available statistics on train density, accidents, and casualties, given in the text, the coefficient of correlation found in each case is shown in the following table. To save needless detail of demonstration, only the total casualties, including fatalities and injuries, are represented in this table, although the number of killed and of injured is separately shown in the text.

Coefficients of Correlation with Train Density of the Specified Classes of Accidents and Casualties.

No. of table.	Page.	Item correlated with train density.	Coefficient of Correlation.
VIII.	..	Collisions	.61
VIII.	..	Derailments	.62
IX.	..	Total casualties to trainmen on the road occurring in collisions	.49
X.	..	Total casualties to trainmen on the road occurring in derailments	.66
XI.	..	Total casualties to trainmen on the road occurring in all train accidents	.61
XII.	..	Total casualties to passengers occurring in collisions	.90
XIII.	..	Total casualties to passengers occurring in derailments	.67
XIV.	..	Total casualties to passengers occurring in all train accidents	.79

BULLETINS OF THE
BUREAU OF RAILWAY ECONOMICS

MISCELLANEOUS PUBLICATIONS

(Continued from page 2 of cover.)

Consecutive Number.	Miscellaneous Series Number.	
4.	1.	A Comparative Statement of Physical Valuation and Capitalization.
21.	7.	The Cost of Transportation on the Erie Canal and by Rail.
34.	12.	A Comparative Study of Railway Wages and the Cost of Living in the United States, the United Kingdom, and the Principal Countries of Continental Europe.
39.	13.	Comparison of Capital Values—Agriculture, Manufactures, and the Railways.
45.	14.	Railways and Agriculture, 1900–1910.
62.	16.	List of Publications Pertaining to Government Ownership.
73.	18.	The Arguments For and Against Train-Crew Legislation.
81.	20.	Statistics of Railways, 1904–1914, United States.
83.	21.	Comparative Railway Statistics, United States and Foreign Countries, 1912.
88.	22.	Summary of Railway Returns for the Fiscal Year Ending June 30, 1915.
92.	23.	Arguments For and Against Limitation of the Length of Freight Trains.

The following Miscellaneous Publications are Out of Print and no copies can be supplied:

Consecutive Number.	Miscellaneous Series Number.	Consecutive Number.	Miscellaneous Series Number.
6.	2.	24.	9.
11.	3.	28.	10.
15.	4.	31.	11.
17.	5.	53.	15.
18.	6.	66.	17.
23.	8.	75.	19.